RESEARCH

FACULTY OF SCIENCE | LUND UNIVERSITY

RESPONDING TO NEW SCIENTIFIC CHALLENGES

Knowledge and research in the natural sciences have laid the foundation for much of modern society's prosperity. However, the rapid development in technology, and consumption, and growing economies have also generated global problems associated with overexploitation of water, land and air. To ensure the wise exploitation of the planet's resources in the future does not only require renewed and strengthened research efforts, but also that politicians and other decision makers become aware of the expanding knowledge in the natural sciences and base their decisions on this knowledge.

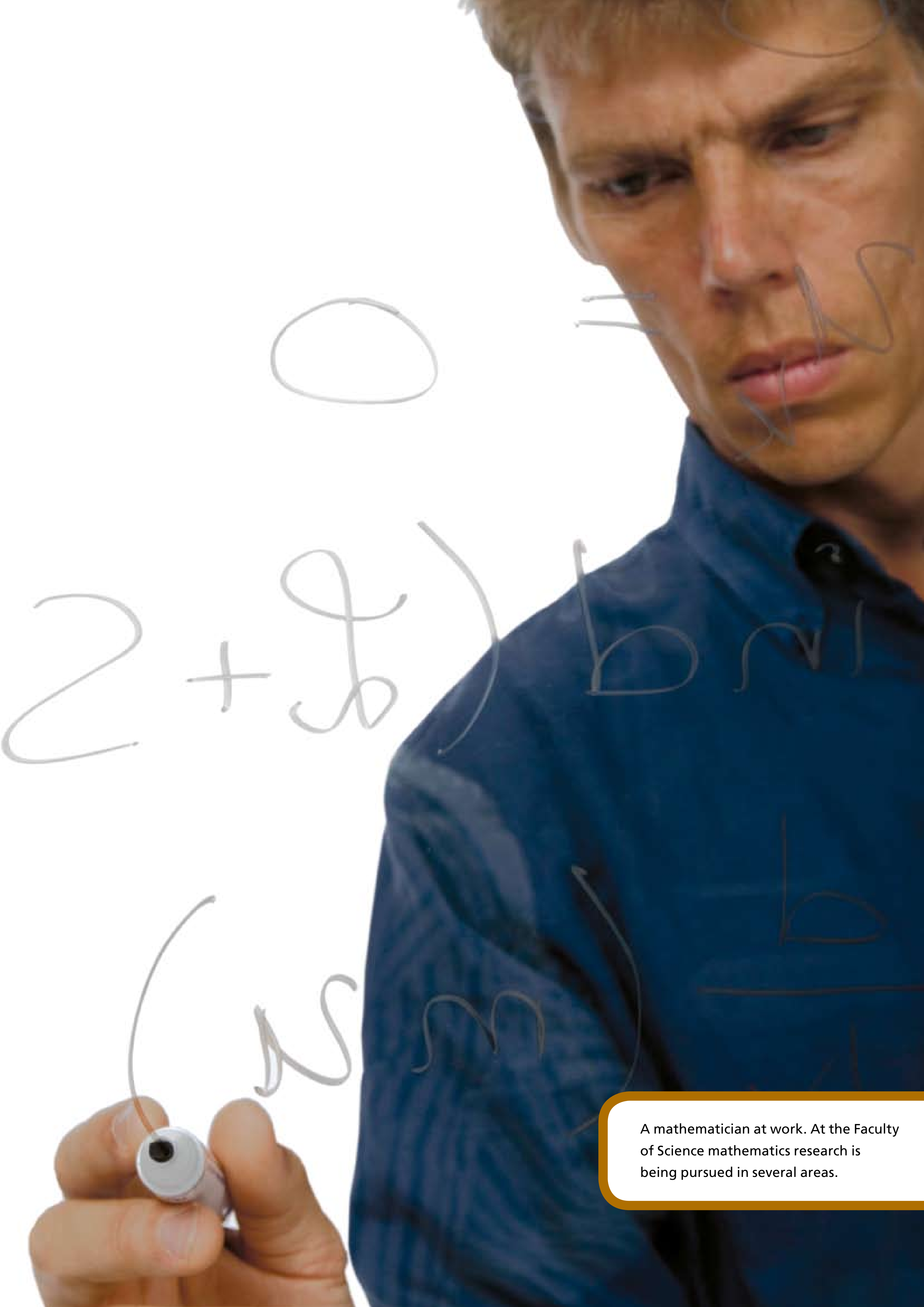
Research at the Faculty of Science at Lund University is characterized by first-class basic research within a variety of areas, from molecular to ecological systems, and from biosphere studies to astronomy and high-energy particle physics. At present there are about 400 graduate students and some 250 senior staff involved in research at the Faculty. This wide spectrum of research, with several world-leading research groups, serves as a platform for applications of the methods and techniques developed within the Faculty´s research programmes. Our ambition is to sustain society's need for applied research without compromising our central quest to promote the progress of basic natural science.

To maintain excellence in research it is increasingly apparent that the Faculty must be able to respond to new scientific challenges, and to redirect resources to areas demanding new research skills, or input from other traditionally separate disciplines. A more flexible allocation of resources will be adopted in response to the changing academic environment. Other challenges include attracting young scientists to new positions, and guiding them through well planned career advancement programmes. In this context it is important to improve recruitment of the underrepresented gender and traditionally non-academic ethnic groups. It is also important to encourage mobility between Swedish universities and universities worldwide.

Our goal is to adopt a policy that is transparent to all faculty members in order to promote creativity and open discussions on science and scientific issues, and the ways in which academia can best meet society's needs and demands on natural science.

The development of the Faculty of Science at Lund University along the lines outlined above has just started, and it is a very special privilege to take part in this and to administer and lead this – in every aspect – great Faculty.

TORBJÖRN VON SCHANTZ | DEAN



A mathematician at work. At the Faculty of Science mathematics research is being pursued in several areas.

MATHEMATICS

Mathematics at the Faculty of Science has long had an outstanding international reputation as measured by publications in leading journals, invitations to work or lecture at leading universities, and requests for professional expertise, for example, in evaluating candidates for academic appointments and serving as a referee or editor for leading journals. At present two recipients of the foremost national mathematics award, the Gustafsson Prize, are active in the section. They work in the areas of algebra, in particular vertex algebras, and non-linear partial differential equations respectively. Another faculty member was recently awarded the internationally prestigious Clay prize for contributions to the theory of linear partial differential equations. Winners of the Clay prize include many of the internationally best known mathematicians.

Most of our PhD students are currently working either in the area of non-linear partial differential equations or in the operator theory for spaces of analytic functions, but research is being pursued in several other areas. In particular, in the theory of linear partial differential equations, spectral theory for differential operators, differential geometry with special emphasis on harmonic mapping, as well as in the theory of vertex algebras.

Mathematical Statistics

Reseach in probability and statistics is concentrated on construction, analysis and application of mathematical models for random phenomena in a very wide range of areas in science, industry and society.

One part of our research concerns the development of general methods with wide applicability. We have research groups in probability, stochastic processes and applied probability, and in statistical theory and algorithms. Their research is directed towards interacting stochastic systems and dynamical random graphs; estimation and simulation in stochastic differential equations with applications in financial statistics and option pricing; Monte Carlo-based statistical methods and methods for partially observed stochastic systems for use in bioinformatics and systems biology; and spatial statistics and statistical imaging. We have a long tradition is statistical extreme value theory, where much effort is devoted to the development of computational tools and strategies and an internationally widely used software package of methods for fatigue and ocean applications. Furthermore, methodological research is being performed in time series analysis and statistical signal processing, especially time-frequency analysis.

We are also deeply engaged in interdisciplinary and applied resarch in engineering and the life sciences. Research is being carried out in biostatistics and public health, bioinformatics and statistical genetics, neuroscience and speech mechanisms, medical imaging and environmetrics. Applications in engineering are metocean statistics and ocean engineering, e.g. stochastic analysis of the risk of capsizing, risk analysis in technological and social systems, stochastic fatigue and load analysis.

COMPUTER SCIENCE

A computer program can generally be described as an algorithm operating on structured sets of data. Therefore, the design and analysis of algorithms together with algorithmic complexity theory, constitute the core of computer science. To meet the increasing demands of the modern society, researchers in the field of artificial intelligence are trying to develop software systems with complex, intelligent behaviour. In Lund, the Division of Theoretical Computer Science at the Department of Computer Science conducts active research in these two fields.

The main research project on efficient algorithms and data structures for combinatorial and geometric problems has been supported by national funding agencies for almost two decades. The primary objective of the project is the design and analysis of efficient algorithms and approximation heuristics within the following five mutually interrelated categories: computational geometry, graph algorithms, data structures, computational biology and communication networks. The other objective is to complement algorithmic results with complexity and approximability hardness results and sometimes even with complexity lower bounds in restricted computational models. The project has been pursued in cooperation with several leading algorithmic groups in the world and it has resulted in hundreds of international publications.

The members of the project actively participate in European projects.

Research into artificial intelligence extends from theoretical models of intelligent systems, through methods for knowledge representation, planning and learning, to implementation strategies in physical robots. The main direction of this research is the investigation of reasoning and learning of resources-aware and, in particular, time-aware rational agents. Another major project, funded by EU, is addressing knowledge representation and reasoning techniques supporting flexible manufacturing processes.

THEORETICAL PHYSICS

The Department of Theoretical Physics consists of two research divisions, Theoretical High Energy Physics and Complex Systems. The department is jointly responsible with the Physics Department for the undergraduate teaching in physics, and exhibits a high profile in outreach activities, with frequent lectures for teachers, schools and general audiences, and a prolific output of physics textbooks and popular science books.

The research carried out at the Theoretical High Energy Physics Division is focused primarily on a deeper understanding of the strong nuclear force. At high energies the fundamental entities are quarks and gluons, and the Lund Model for quark-gluon dynamics has been continuously improved and extended since its conception in the late 1970s. Together with its implementation in computer simulation programs it has developed into an international standard. Since 1997 the interest of the group has been widened to include hadron dynamics at lower energies.

The Complex Systems Division, established in 1989, today mainly carries out research within computational biology and biological physics. Initially, the focus was on machine learning and combinatorial optimization algorithms with pattern recognition, and scheduling problems as targets. Gradually interest developed in the life sciences; the properties of macromolecules including protein folding and design becoming key areas of study. The past five years have been dominated by functional genomics and systems biology, in close collaboration with biomedical groups within and outside Lund University.

PHYSICS

The department of Physics is an inter-faculty department with roughly 290 employees organised in a number of divisions. The Department is presently composed of nine research divisions, four of these belong to the Science Faculty and the remaining five to the Engineering Faculty (known as LTH in Swedish). One of the divisions, Nuclear Physics, is an inter-faculty division. The various divisions are of different sizes; the three largest belonging to the Engineering Faculty.

Divisions belonging to the Engineering Faculty:

Atomic Physics, Combustion Physics, Mathematical Physics, Nuclear Physics, Solid State Physics. Divisions belonging to the Science Faculty: Experimental High-Energy Physics, Nuclear Physics, Synchrotron Radiation Physics, Solid State Theory.

The research areas covered by the scientists in these divisions can be divided into six domains:

- Nanometre Science and Technology
- Laser Science and Technology
- Combustion Science and Technology
- Sub-atomic Physics
- Synchrotron Radiation-based Science
- Theoretical Physics

The department includes several centers of competence and large-scale facilities, and the divisions frequently collaborate with other departments at Lund University and abroad. Our researchers are involved in numerous EU projects and coordinate several large European projects. Two of our divisions coordinate two programs within the recently SSF-program ”Strong Research Environments”. The divisions are involved in four out of the ten centers chosen by LU as candidates as Linné-centers. The most important laboratories and associated centres on site are the Lund Laser Centre, The Nanometer Structure Consortium, The Centre for Combustion Science, The Nanometer Laboratory, the mobile LIDAR monitoring facility and the microbeam accelerator. The two sub-atomic physics divisions mainly carry out their experimental work at large international centres abroad such as CERN in Switzerland, Brookhaven National Laboratory, USA, and DESY in Germany. Some of our scientists hold important top positions as spokespersons.

High-Energy Physics

High-energy physics is a branch of science which studies elementary particles and their interactions. According to the experimentally well-tested Standard Model there are six quarks, six leptons and four forces carried by mediating force particles. However, the Standard Model is in many respects not a complete theory, so new discoveries are expected at the next generation of experiments. One of the new particles which is expected to exist according to the Standard Model is the Higgs particle, which can explain why most elementary particles have mass. The best candidate for an improved theory beyond the current Standard Model is a theoretical framework called Supersymmetry, which predicts a new symmetry, boson-fermion symmetry, and consequently there should be new boson partners for all the known fermions (half-spin particles, i.e. matter particles), and new fermion partners for all the known bosons (integer-spin particles, i.e. particles mediating interactions).

Through colliding heavy nuclei at high energies we can create similar conditions to those in which the universe existed moments after its creation. In heavy-ion collisions, extremely hot, dense nuclear matter can be produced, and it is expected that this matter will melt into its constituents, quarks and gluons. Scientists are searching for a phase transition from ordinary nuclear matter to this new type of matter, called the quark-gluon plasma. The universe is believed to have existed in such a phase for a few microseconds after its creation in the Big Bang.

The experiments in which the Division of Experimental High-Energy Physics is currently involved, are the ongoing H1 experiment at the HERA electron–proton collider at DESY, Germany, studying the proton structure, and the heavy-ion experiment PHENIX, at the Brookhaven National Laboratory in the United States. In 2007, the Large Hadron Collider, LHC, will start operating at the European High-Energy Physics Laboratory, CERN, in Geneva, Switzerland. Lund is involved in two of the major experiments, the ATLAS experiment, which is looking for new particles such as Higgs particles and supersymmetric partners of ordinary particles, and the ALICE experiment, through which it is hoped that the existence of the quark–gluon plasma will be confirmed.

Nuclear Physics

Within the Division of Nuclear Physics, both basic and applied research are carried out, the latter also within the Engineering Faculty (LTH). This research is highly regarded, nationally and internationally.

The aim of our basic research is to study the behaviour of nuclei when excited far away from their ground state, i.e. to reach states of high temperature, high pressure and/or high instability. To achieve these states we study collisions between particles and nuclei, or between two nuclei, at leading accelerator facilities throughout the world. Apart from providing knowledge on the interesting quantum mechanical systems represented by nuclei, this research also provides us with information that is important in understanding how the elements are formed in stars and supernovas. The Division is also engaged in nuclear physics research using photons at the MAX Lab in Lund, together with international groups. Furthermore, we are involved in exceptionally fruitful collaboration with theoretical physicists, especially on our home ground, i.e. Lund and Copenhagen.

This detailed knowledge in nuclear physics and the techniques employed have led to a wide spectrum of applications of use to society. A number of joint projects are in progress between basic and applied research groups in several disciplines. One example of this is the work being carried out in AMS, accelerator mass spectroscopy. The technique has been developed at the Pelletron accelerator at the Department of Physics, and efforts are now being concentrated on the new single-stage AMS accelerator, which has recently been commissioned at the Department of Geology at Lund University. The close collaboration between these two departments will continue with this accelerator, and will be concentrated largely on the application of 14C analysis, which can be applied to a number of interesting areas of research such as medicine, pharmaceuticals, food products and aerosols.

The competence of nuclear physicists in Lund and the good results they have obtained have often been achieved through the development of innovative experimental equipment in collaboration with high-tech industries and other leading experimental groups worldwide. The work described above constitutes the basis for a lasting, coherent programme of nuclear physics research for many years to come.

MAX-Lab, the national facility for synchrotron radiation is situated in Lund. Advanced spectroscopy is being developed and used at its beamlines.

Solid State Theory

Research at the Division of Solid State Theory is driven both by theoretical principles and experiments, and interests range from numerical simulations to analytical techniques. An essential part of our research is carried out in collaboration with several research consortia and institutes in Sweden and around the world. Principally, the research can be divided into two main areas: density-functional theory, excitation energies and spectra and the physics of mesoscopic and low-dimensional structures. Some of the on-going research projects concern conduction in atomic and molecular wires, electron correlations in strong laser fields, physics of mesoscopic and low-dimensional structures, THz lasers, Bloch oscillations in semiconductor superlattices, hot-electron effects, solid-state power generation and refrigeration, coherent spin polarized transport and quantum computation.

Synchrotron Radiation Research

Research at the Department of Synchrotron Radiation Research is largely of an experimental nature. Important research goals include understanding the geometric and electronic structure of materials ranging from free atoms and molecules, surfaces and interfaces to artificially nanostructured materials with the ultimate goal of unravelling how the macroscopic function and behavior of materials are related to the atomic scale electronic and geometric structure. Much of this research leads to an increase in our fundamental understanding of the basic properties of these systems, but applications can be found within the areas of catalysis, nanoscience, atmospheric chemistry, electronics, device physics and plasma physics.

We also develop and make use of advanced electron spectroscopic techniques to probe the electronic structure, e.g. the atomic energy levels, of materials and to follow changes in this electronic structure on timescales relevant for the formation and breaking of chemical bonds between atoms. In addition to techniques based on the electronic structure, we also use diffraction methods as well as scanning tunnelling microscopy (STM) to study the geometrical structure. Finally, advanced theoretical simulations based on a quantum mechanical description of matter are integral parts of our research.

The Department has implemented and maintains sophisticated spectroscopic instrumentation at the MAX-lab national facility for synchrotron radiation in Lund, carries out much of its synchrotron-radiation-based research there, and is deeply involved in new developments including plans for the future MAX IV light source. Work within the group is also carried out at several other European and international synchrotron radiation sources. Members of the Department are involved in a large number of national and international collaborations including the coordination of national as well as international EU-funded networks.

MEDICAL RADIATION PHYSICS Lund

The Department of Medical Radiation Physics at Lund University was founded approximately 50 years ago as a result of the increasing demand from the University Hospital for expert knowledge concerning the medical implementation of ionizing radiation. While the focus of the Department´s research was formerly on the interaction of ionizing radiation with matter and dosimetry, the scope has since widened to encompass non-ionizing electromagnetic radiation and its medical applications. Our research groups (see below) cover a wide range of topics within the field of ionizing and non-ionizing radiation, including basic research, medical applications for diagnosis and therapy, and investigations of health effects. Owing to the very close collaboration with the Lund University Hospital, our research groups have access to state-of-the-art equipment, for example in the fields of medical imaging and radiation therapy. This research is international and we have numerous research contacts within Scandinavia and Europe and other countries worldwide.

Research in the field of oncological radiation physics has the ultimate goal of giving an exact, appropriate absorbed dose to a well-defined tumour volume while minimizing the irradiation of normal tissues. To accomplish this, several routes are being explored at the Department.

In the field of non-ionizing radiation, the same research group has studied the effects of electromagnetic radiation from mobile telephones for more than a decade. The permeability of the blood-brain-barrier has been observed to increase after exposure.

The goal of the research group is to develop methods for diagnostics and therapy using radionuclides based on quantitative imaging and dosimetry. The group is developing imaging methods from the macroscopic level using scintillation cameras, SPECT and PET systems, to the microscopic level using solid-state autoradiographic systems.

The MR physics research group is active in the field of medical magnetic resonance, and has its primary focus on development of new functional techniques for the assessment of microcirculation (perfusion), macrocirculation (flow) and molecular motion (diffusion). The group is presently engaged in research on high–field MRI platforms at 3 Tesla and above.

The task the environmental radiology group has set themselves is to assess the impact on man and the environment of the release of radioactivity due to different practices such as nuclear tests, nuclear accidents and controlled releases. The laboratory has been contracted by the Swedish Radiation Protection Authority as an emergency resource due to its unique experience in radiochemistry analysis and in situ radiation metrology.

Malmö

The research in Malmö is concentrated on new improved methods of medical X-ray imaging, nuclear medicine imaging, magnetic resonance imaging and radiation therapy as well as the analysis of radioactive and stable elements in the human body. Absorbed dose determinations and radiation protection research related to patients, occupationally exposed workers and the general public are essential parts of our research.

We are developing a water calorimeter as a national resource for the absolute determination of absorbed dose. The main task is the development of a new 3D dose meter using polymer and Fricke gels. This is currently the only technique that can be used to measure 3D dose distributions in anatomically shaped phantoms and to verify treatment planning calculations with one exposure. We are also developing small dose meters connected to optical fibres for continuous measurements of dose rate and total absorbed dose using radioluminescence (RL) and optically stimulated luminescence (OSL) respectively. We are currently also using an OSL technique to develop methods for retrospective dosimetry in connection with radiological accidents.

The relation between physical/technical parameters, the information content of the image and the patient dose is being investigated. The results will form the basis for the determination of the operating conditions for digital radiography, to guarantee an image quality sufficient to meet the diagnostic requirements with minimum of irradiation of the patient.

New, improved methods for studies of body composition, nutrition, toxicology (lead and cadmium in vivo) and general medical research are being developed. The focus is currently on exploiting the potential of accelerator mass spectrometry (AMS) for ultra-sensitive analysis of 14C (down to atomic levels) in small biomedical samples in cooperation with the Department of Nuclear Physics.

We have published biokinetic and dosimetric data for different radiopharmaceuticals which are now used by the International Commission on Radiological Protection (ICRP). In other programmes, we are determining the radiation dose to the general public from natural and man-made sources, including the reactor accident at Chernobyl.

ASTRONOMY

Scientists at Lund Observatory, the University's department of astronomy, are striving to promote observational, theoretical and laboratory astrophysics, as well as concepts for, and the design of, world-leading telescopes. All our scientific projects are funded through international competition, usually with world-leading research organisations, which ensures the high quality of our research.

Our observations – often with the world's largest ground-based telescopes and sophisticated space telescopes – theoretical work and modelling cover the formation, development and dynamics of galaxies, stellar clusters, stars and planets, as well as black holes and neutron stars. Corresponding laboratory work provides spectral-line data helping us to explain what we see. In response to scientific demands, our scientific and technical staff are involved in international consortia that are developing concepts and designs for future


Geologists from Lund coring peat deposits at Abisko in Northern Sweden.

telescopes, explicitly aimed at world-leading sophistication and power. PhD students are integrated into research groups and work in close collaboration with their advisors and other scientists, including international partners.

An EU project is funding research which will result in a European telescope, the world's largest and most sophisticated, hopefully operational in 2017. The intention is for the primary mirror to have a diameter of at least 50 m. The Lund Observatory is also host to a collaborative programme with four other institutes in the Swedish National Centre for Adaptive Optics. Another field of research is the development of ESA's Gaia Satellite for parallax measurements.

The Lund Observatory also has a division for atomic physics, continuing a tradition spanning a century in Lund. This discipline has now been integrated with astrophysics, and is carrying out investigations of the structure of atoms and ions, studies of atomic and plasma processes, and spectroscopic diagnostics of astrophysical and laboratory plasmas.

GEOLOGY

The Department of Geology now has two divisions: Lithosphere and Palaeobiosphere Sciences and Quaternary Sciences. Our research thus extends from processes occurring deep in the earth's interior and their evolution, to the external processes of our earth and their long history, as well as the evolution of life over millions of years and very recent changes in the earth's ecosystems and climate.

In the field of lithosphere science mineral-oriented research is being carried out through studies of chemically and biologically induced weathering processes and of the resulting fine-grained minerals. On a larger scale research covers areas such as metamorphism and magmatism, large-scale deformation and terrain analysis in time and space, as well as more superficial processes, such as volcanic eruptions and weathering. Sedimentary processes are other important areas of study.

In palaeobiosphere science the development of life as recorded in the sedimentary archives of the past 550 million years is a prominent area of study. Lund has a long and distinguished record of palaeobiosphere research, extending well back into the 19th century. Currently, the main subjects being studied are evolutionary events and trends, biotic diversification, and faunal and floral turnover. The history of the carbon cycle and its relation to climate is also being studied. Research also deals with cross-disciplinary issues in the borderland between astronomy and geology, for example, how the meteorite and asteroid flux to earth has varied through time, and the effects it has had on life.

Quaternary sciences involves the study of the Pleistocene and Holocene soft sediments of biogenic and inorganic origin, covering older basements. Our research is focussed on glacial processes and glacial history, sea-level changes, climate evolution and its underlying mechanisms, including the carbon cycle, the floral and faunal history of the most recent glacial cycle, and early anthropogenic impact on the landscape. A certain amount of palaeoclimatic research is also being carried out. The projects are global, covering areas from Greenland to Antarctica. An AMS radiocarbon laboratory and two National Resource Units are attached to the Division of Quaternary Sciences: the Laboratory for Ceramic Research and the Laboratory for Wood Anatomy and Dendrochronology. These two laboratories serve as national centres for research and education within their special fields of competence.

Recent years have seen a series of important events influencing the growth and strengthening of our teaching and research work. In 2003 the Departments of Geology and Physical Geography and Ecosystems Analysis combined to form a "GeoBiosphere Science Centre". The relocation of all the geoscience departments to new premises, The Lund GeoCentre, was a very significant step. From seven different addresses we moved into a building with some 11,000 square metres, consisting of two totally renovated, beautiful old buildings and a new one. Vitalization of geological research can clearly be seen within this new centre, not least in the funding of high-tech, state-of-the-art instrumentation.

PHYSICAL GEOGRAPHY AND ECOSYSTEMS ANALYSIS

Traditionally, the main purpose of Physical Geography has been to explain the spatial characteristics of the various natural phenomena that exist in the hydrosphere, biosphere, atmosphere and lithosphere. In Lund, the spatial focus has been complemented by studying the interactions between the different spheres and thus the functioning of the whole terrestrial system. This research is highly interdisciplinary and in most cases is pursued in collaboration with international partners. The largest part of the funding for research has been acquired externally under strong international competition, reflecting the high quality of the science, with many publications in high-impact journals.

Core research areas include biogeophysics and biogeochemistry, addressing fluxes of energy and matter between soils, vegetation and the atmosphere; modelling of terrestrial ecosystem dynamics; remote sensing; geomorphology (land-forming processes, such as soil erosion and permafrost); climatology; and geographical information systems (GIS).

Knowledge from the different subdisciplines is combined to improve our understanding of the terrestrial system, by which human impacts and services provided by ecosystems to society (e.g. clean water, food and carbon sequestration) receive special attention. Ecosystem models are tested against results from field experiments and are then used to scale up patterns of carbon and water cycling observed on a local scale to a regional or global scale. Modelling also includes projecting potential future impacts of climate change on food production, forestry and biodiversity. Satellite-derived remote sensing data present another independent means of monitoring the biosphere, including, for example, changes in human land use and availability of natural resources. Advanced GIS techniques are used to analyse and visualize environmental data, and to make research results accessible to decision makers, such as local planners, in a number of developing countries.

CELL AND ORGANISM BIOLOGY

The Department of Cell and Organism Biology was established in January 2002. Research and teaching activities within the Department cover biology at all levels, from populations and individual organisms (animals, plants and micro-organisms), to cells and biomolecules. Extensive interactions and collaboration with scientists in the disciplines of medicine, technology, physics, chemistry and ecology make both undergraduate teaching and research at the Department largely interdisciplinary. The Department is located in four separate buildings, but an ongoing process is aimed at housing all the activities, together with the Department of Ecology, in a new Centre for Biology. A staff of around 100 provides skills and facilities for undergraduate and postgraduate education for approximately 1400 students per year. About ten doctorates per year in biology are the outcome of research and postgraduate studies within the subdisciplines of genetics, integrative zoology, microbiology, plant biology and zoological cell biology. Research and postgraduate education are carried out within three areas: 1) neuro- & sensory biology, 2) genetics, evolution & systematics and 3) cell & molecular biology, which to various degrees cross the subdiscipline borders.

Neuro- & Sensory Biology

The Vision Group is investigating the function and evolutionary adaptation of animal's visual systems. The group works on many different animals, from jellyfish to man. Some of the specific research questions concern how eyes and vision originally evolved, and how this led to the modern diversity of eye types. Other areas of study are specialisations for vision in poor light, and colour vision. One project is aimed at understanding the multi-focal lenses that were discovered by members of the group and which have been shown to be generally prevalent among vertebrates. The various projects in progress employ a multitude of experimental techniques, many of which have been developed within the group. Morphological, optical, electrophysiological and behavioural approaches dominate, and special emphasis is placed on non-invasive techniques. Sensory biology also includes research on the chemosensory system and chemical communication in crustaceans.

Another major research area within the Division of Neuro- & Sensory Biology is the molecular mechanisms behind nerve regeneration, in particular the signal transduction events that are induced by nerve injury, the transcription factors activated and the expression of new regeneration-related proteins. The knowledge gathered in this research is being used in an extensive interdisciplinary project in an attempt to construct an electronic interface between neurons and computers. Independent research projects related to the above concern the development of the alimentary canal and the pancreas, as well as cardiovascular adaptation to the environment.

Scientists investigate the colour vision of moths at a laboratory within the Department of Cell and Organism biology.

Genetics, Evolution & Systematics

The genome is the focus of much research in biology today. A shared interest in genome evolution unites scientists working in genetics, evolution & systematics. The evolutionary relationship between organisms, especially vertebrates, is being explored using DNA sequence data. Several projects focus on the evolution of small mammals and plants, for instance the effects of glacial periods on genetic divergence and speciation. An example of horizontal gene transfer is being studied in grasses, and the question of how genomes evolve is being studied in yeast.

The Insect Systematics Group is carrying out basic biodiversity research on poorly known groups of insects, specifically those of the order Hymenoptera, found in tropical America and Europe, and on microsporidia: which species exist, how they differ from one another, and the ways in which they are related.

Cell & Molecular Biology

Research within this field is to a large extent molecular and includes bacteria, yeast, plant and animal (human and fish) cells and also viruses.

Our research on mammalian cells concerns regulation of cell cycle progression and apoptosis with the goal of achieving a better understanding of normal and cancer cells. Another goal is to find molecular markers for sensitivity to chemotherapeutic and immunological treatment of cancer. The cell lines used are mainly of human cancer origin with special emphasis on breast, prostate and bladder cancer, as well as the childhood tumour neuroblastoma. Work is also in progress on the development of in vitro techniques for the evaluation of toxicity to replace animal testing.

Our plant molecular biology research focuses on functional analysis of the cytoskeleton and plasma membrane, sugar metabolism, stress signalling and plant respiration, using wild-type/transgenic model plant and cell systems. One line of research concerns stress-related MAP-kinase substrates/interacting proteins in an effort to understand the biological roles and biochemical specificity determinants of these signalling molecules. In another project we are investigating a specialty of plants – they have several enzyme systems that decrease the energy efficiency of respiration – to see how respiration is regulated and how the "energy-wasting" respiration supports other plant processes.

The research into micro-organisms within the Department includes yeast and bacteria, as well as virus biology and antibiotic resistance in natural habitats. One subject of research concerns the function and properties of enzymes in the metabolism of nucleic acid precursors. In another project yeasts are being used to functionally study the ends of chromosomes, or telomeres. Several groups have specialized in the Gram-positive bacteria, which include major human pathogens and bacteria of considerable industrial importance. This research on Gram-positive bacteria concerns biogenesis and the function of membrane proteins, which are important for energy conversion and metal detoxification, mechanisms of cell division and cell differentiation, and systems for intracellular signalling.

The aims of the projects involving viruses, yeasts and bacteria are to increase our understanding of the role of micro-organisms and viruses on earth, to increase our knowledge of cellular processes, and to aid in the development of new drugs against pathogenic micro-organisms and cancer.

ECOLOGY

Ecology is a very wide subject, including ecosystem-oriented aquatic and terrestrial ecology; organism-oriented microbial, plant and animal ecology; model-oriented theoretical ecology; chemical ecology focusing on signal substances; and applied ecology, e.g. ecotoxicology. All these aspects are covered by the Ecology Department in Lund, one of the largest of its kind in the world, with approximately 170 academic staff, technicians and PhD students.

The Ecology Department is housed in the recently constructed Ecology Building, with excellent facilities for laboratory work including a wind-tunnel for bird flight experiments. State-of-the-art analytical and culturing equipment is a necessity bearing in mind the rapidly growing focus on DNA and gene-based ecology. Although research at the Ecology Department mainly addresses fundamental problems in biology, we are also very active in several areas of applied research. This includes conservation biology, pest control, effects of alien species and gene-modified organisms, and the management of exploited populations. The Ecology

Building is a truly international environment, with a high proportion of students and scientists from abroad. A wide variety of courses is available in all branches of ecology, many of which are given in English.

Theoretical Ecology

Theoretical ecology is the study of almost all aspects of ecology and evolution under the assumption that is possible to formalize and generalize the important states and processes by using a variety of mathematical tools. Research in Lund deals with biomechanics and the functional morphology of animal flight, behavioural ecology (food hoarding and mate selection), stochastic processes in populations, communities and their environments, and the process of evolution and speciation. Flight mechanics and aerodynamics, neural networks, adaptive dynamics and state–space modelling are examples of the tools and approaches used.

We collaborate with a large number of research groups within and outside the Ecology Building, in areas such as large-scale and long-term field experimentation, wind-tunnel experiments and climate research.

Microbial Ecology

Microbial ecology is the study of the function of micro-organisms in the environment. Our research is focused on the role of micro-organisms in important ecosystem processes such as decomposition and nutrient cycling, particularly in soils. Fungi and bacteria are the main decomposers in soil. We are analysing how environmental factors and anthropogenic perturbations, like pollution, can enhance or reduce the activity of these organisms in soil. An important group of soil fungi forms mutualistic relationships with plants. In these associations, called mycorrhizae, the fungal partner obtains photosynthetic sugars from the host plant, while in return the plant receives mineral nutrients from the fungus. We are studying the molecular mechanisms and ecological importance of this transfer of nutrients and carbon in different types of mycorrhizal associations. We are interested in the evolutionary history of mycorrhizal relationships and how they are affected by disturbances in the environment.

Animal Ecology

In animal ecology one of our research groups is using modern molecular tools to investigate ecological and evolutionary issues, among other things, population divergence, immunoecology, co-evolution between malaria parasites and bird hosts, and genomic ecology. Others are addressing problems in evolutionary population biology, such as the strength of natural and sexual selection, ecological evolution of colour patterns, gene flow and evolutionary conflicts of interest. Research is also focussed on functional mechanisms, for example, those related to energy turnover rates, resistance to infections and parasites, and the action of hormones, all of which interact with the environment to form individually optimized life history strategies.

Human activities may create landscapes in which the quality of animals' habitats shows large spatial variation and in which good habitats become fragmented. The way in which animal populations are affected by this is the subject of another research group.

The Soil Ecology Group is developing methods for detecting interactions between cryptic organisms and is using DNA techniques to detect the identity of interacting organisms, fatty acid signatures of micro-organisms and natural abundances of stable isotopes, as well as pulse labelling of carbon and nitrogen to detect the directions and complexity of these interactions.

The general objective of the Migration Ecology Research Group is, through research and teaching, to improve our understanding of adaptive values and evolutionary opportunities and limitations in animal migration, flight, orientation and energetics. The methods used range from theoretical evaluations of optimal migration to the use of highly advanced observational and experimental techniques: orientation cage experiments with manipulation of geomagnetic and visual cues, radar and satellite tracking studies of migrating birds and sea turtles, and aerodynamic and energetic evaluations in wind-tunnel experiments.

Limnology

A number of researchers at our department are interested in how the migratory behaviour of aquatic organisms affects other trophic levels and nutrient distribution in lakes. They are also studying newly constructed wetlands in agricultural areas, especially the emission of greenhouse gases from ponds and the biodiversity within wetlands. Others are focusing on the role of crayfish in freshwater food chains and the dynamics and bioaccumulation of organic pollutants.

Specific research programmes include studies of the mechanisms behind and effects of seasonal mass-migration of cyprinids between lakes and tributaries. Predator–prey interactions in freshwater habitats is another line of research. Others concern the ecology of freshwater heterotrophic and mixotrophic microbes, in terms of both trophic interactions and their role in biogeochemical cycles.

Modern molecular tools are of course also being used in limnology, among other things, to study the genetic diversity and phylogeography of dinoflagellates.

Plant Ecology and Systematics

Regarding research within plant ecology and systematics ecologists are engaged in basic research and problems within conservation biology and environmental management, and to these ends use a range of techniques such as field studies, experiments, molecular methods, image analysis and chemical analysis. Systematics also includes studies of the mechanisms that control the spatial patterning of variation in plant populations and species. Another line of research addresses the effects of pollen donor and environment (e.g. temperature and the nutritional status of donor and recipient plants) on the success of pollination. Broader studies are also being pursued on the relationships between local environment and plant populations and communities, and on the functional roles of plants in ecosystems. Effects of soil nutrient limitation, toxic elements and the availability of inorganic and organic nutrients on wild plants are also being investigated.

Chemical Ecology and Ecotoxicology

Research at the Division of Chemical Ecology and Ecotoxicology deals with chemical interactions between organisms and between organisms and their environment. The effect of chemical factors on the distribution of plants, animals and micro-organisms is being studied. Ecosystems in water and in the soil are being investigated with the aim of describing chemical and ecological relations, including trophic interactions and biodiversity, as well as to predict changes caused by natural and anthropogenic compounds. The transport of organic pollutants, metals, nitrogen and carbon in the ecosystems, and the impact of micro-organisms on these processes are being investigated. Insect chemical communication, for example, mate and food choice by means of chemical signals, is being studied in an evolutionary and ecological perspective by means of chemical, neurobiological and genomic tools. Some projects deal with biological clocks controlling insect communication by chemical signals. Several of the research projects at the Division are of an applied nature; for instance, the development of methods for biorational insect control, risk analysis and remediation of polluted environments.

CHEMISTRY

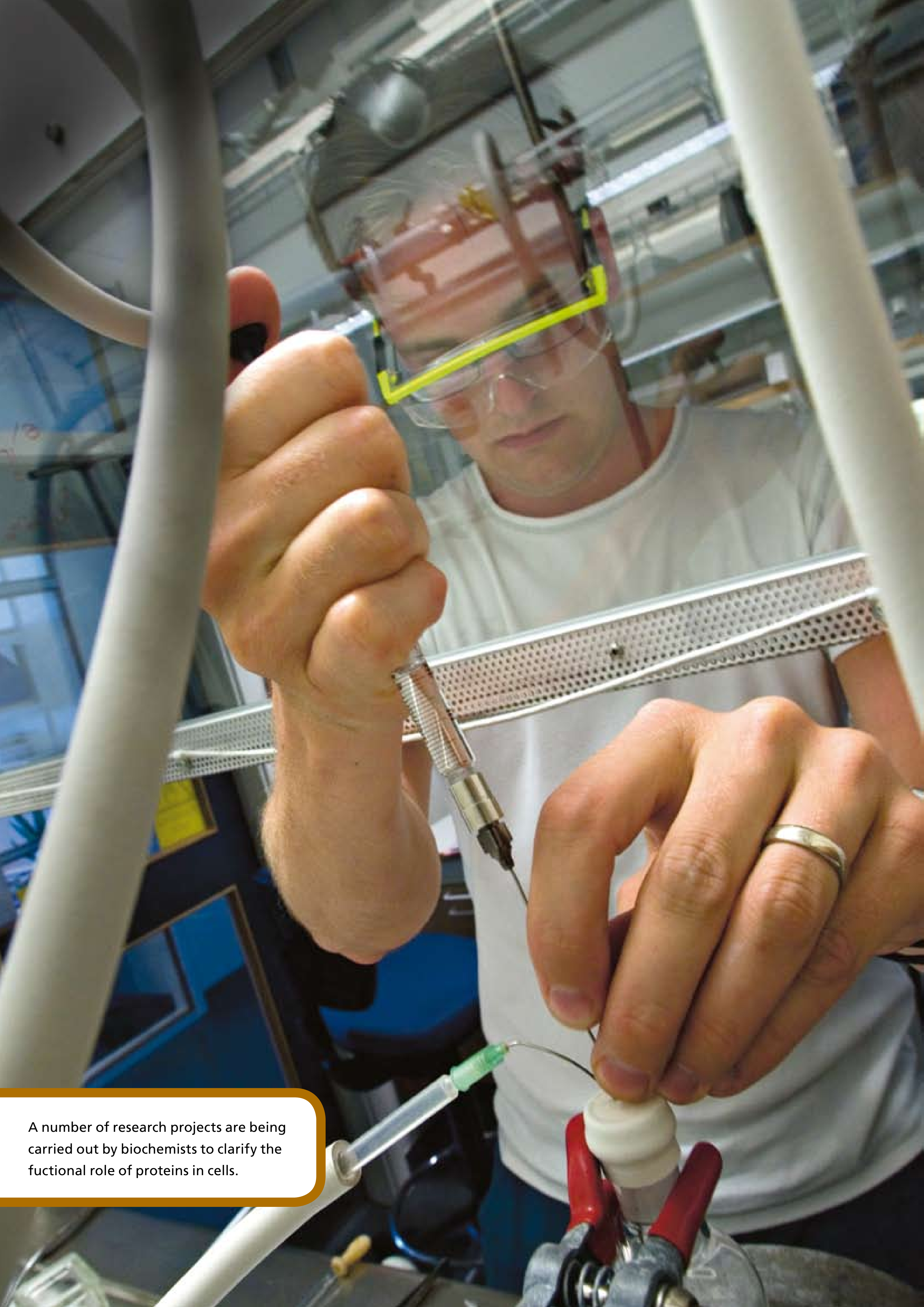
The Center for Chemistry and Chemical Engineering was built during the period 1964-1968. The idea then was to collect all those working in chemistry in Lund in one department covering the three faculties of Engineering, Medicine and Science. Since then, things have changed. The medical chemists have moved into the Biomedical Centre (BMC), biochemistry has grown and filled the vacancy left by them, and the Chemical Centre has been divided into three departments; the Department of Chemistry with around 400 employees and 600 undergraduate students being the largest.

The Department of Chemistry is jointly run by the faculties of Engineering and Science. The two parts are of almost the same size and there is no clear borderline between science and engineering, rather a gradual change from theoretical chemistry to biotechnology. The Department is today organised in 13 research divisions. Seven of these belong to the Faculty of Science:

- Theoretical Chemistry
- Chemical Physics
- Physical Chemistry
- Organic Chemistry*
- Analytical Chemistry*
- Biochemistry
- Molecular Biophysics

* jointly with the Faculty of Engineering

Using wind-tunnel experiments, animal ecologists study the aerodynamics and metabolism of flying birds.



A number of research projects are being carried out by biochemists to clarify the fuctional role of proteins in cells.

The research within these areas carried out by scientists from the Faculty of Science is described below.

Theoretical Chemistry

The Division of Theoretical Chemistry performs research in quantum chemistry and statistical mechanics. Comprehensive efforts are being devoted to the development of methods and computational tools and strategies. This has resulted in world-leading computer software for chemical modelling. The software systems MOLCAS, for quantum chemical modelling, COMQUM, for combined classical and quantum chemical modelling, and NEMO, for intermolecular interaction, have been merged into one program system and commercialized under the name of MOLCAS.

The methods developed are applied to chemical problems in such areas as molecular spectroscopy in the gas and liquid phase, chemical reactions, the physical properties of molecules, intermolecular interactions, protein–ligand interactions, protein–protein interactions, surface and colloid chemistry in general and the behaviour of polymers in confined volumes, as well as dielectric phenomena and the hardening of concrete.

Further applications can be found through investigations of the function of metalloproteins and in the improvement of protein crystal and NMR structures.

During the past year special attention has been directed towards the study of actinides by theoretical means. This is a field where experimental work is extremely expensive, but it is also a field where the unique properties of the MOLCAS system make it the only possible theoretical tool, due to the complicated electronic structure of these atoms.

Chemical Physics

Our research aims at obtaining new basic knowledge concerning chemical and biological processes that can be applied in materials science, energy conversion and medicine, for example.

Solar energy will be an important source of energy in the future. Therefore, we need to find ways to convert solar energy into energy-rich fuels or electricity. Our research is thus directed towards obtaining knowledge that can be used to develop new solar cells and methods for light-driven chemistry. This knowledge can also be used for developing novel materials for light sources, displays, sensors, etc.

In addition to being an inexhaustible source of energy, sunlight has many harmful effects on living organisms, e.g. causing skin cancer, but the reasons and underlying mechanisms are poorly understood. We are therefore searching for new knowledge about chemical processes and protection mechanisms in living tissue initiated by UV light. It is hoped that this may lead to new therapies and drugs.

We are studying basic chemical reactions that may provide important knowledge that will help us to understand biological processes, develop new drugs, understand the chemistry of the atmosphere, and develop new catalysts. Nature, on the other hand, is an excellent source of inspiration for the development of new materials and processes; we therefore often work with biomimetic materials.

New knowledge requires new methods, and we are thus engaged in developing new methods in microscopy and spectroscopy to be implemented in materials science, biology and medicine.

Physical Chemistry

Research at the Division of Physical Chemistry is focussed on colloid science. This area is approached from a broad perspective ranging from basic considerations of intermolecular interactions and their manifestations in condensed systems, to practical consequences in industry and medicine. Research areas include molecular assembly, adsorption and colloidal biology. In each research project, we strive to combine a theoretical description with experimental studies of the basic physicochemical phenomena and utilize the findings in applications.

In an aqueous environment molecular assembly is governed by the interplay between polar (electrostatic) and hydrophobic interactions. Here, we are today mainly focussing on non-equilibrium systems in an effort to gain a molecular understanding of various processes, such as vesicle fusion and the formation of mesoporous inorganic materials.

An aqueous sample is always bounded by an interface to a solid, another liquid or to a gas phase (air). For many practical purposes it is important to control the adsorption of solutes onto these interfaces or surfaces. Adsorption can be used to control surface properties such as adhesion and friction, and is also a common method of achieving colloidal stability/instability.

Organic Chemistry

Traditional organic chemistry concerns the chemistry of molecules containing carbon, i.e. the molecules of living matter. Today, organic chemistry has developed mainly into a science where attempts are made to understand the chemical processes that constitute life and how these can be affected by low-molecular-weight compounds specifically designed for a specific purpose.

Chemical biology is the use of small organic molecules as tools in life sciences with special emphasis on constituents of fungi and medicinal plants, DNA recognition, tubulin-modulating molecules and glycobiology. Some of these studies are focussed on the development of novel types of structures that may be potential drug candidates.

Researchers are also working on the isolation, characterization and synthesis of biologically active natural products, in order to understand their purpose in nature and to use them as bioorganic tools. New synthetic methods, with special emphasis on asymmetric synthesis and ligand construction, are also being developed.

Chemical studies are being carried out on self-assembly and supramolecular catalysis,as well as various host–guest phenomena of synthetic receptors.

"Green chemistry", with the general goal of developing new reactions and reaction conditions that make it possible to synthesize organic molecules, also in an industrial scale, in a more environmental-friendly way and at a lower cost, is also being studied.

Others are working on the coordination chemistry of transition metals and main group metals from simple solvated cations to organometallic compounds, in order to study clusters and bioinorganic model systems.

The study of bioorganic stereochemistry and SARs (Structure Activity Relationships), using computational modelling and the design of novel biologically active compounds are other areas of research pursued within the Division.

Analytical Chemistry

The research at the Division of Analytical Chemistry is directed towards combining traditional and modern aspects of analytical methodology with bioanalytical tools. This combination gives valuable insight into the mechanisms of biological and environmental chemistry and thus helps establish the basis for new analytical systems.

Areas such as mass spectrometry, bioelectrochemistry (biosensors), bioaffinity assays, separation methods (gas and liquid chromatography, capillary zone electrophoresis) and the analysis of macromolecules (proteins, polysaccharides) are being studied.

Special attention is being devoted to methods for the pretreatment (i.e. clean-up and enrichment) of aqueous samples, e.g. liquid membrane extraction and microdialysis. Modern extraction methods for solid samples, such as supercritical fluid extraction and microwave-assisted extraction, are also being developed. Applications are mainly found in environmental science, but also in pharmacology, biology and food science.

Biochemistry

Modern biochemistry is characterized by the impact of the rapid and extensive advances in genomics that have led to sequencing of the entire genome of a large number of organisms. This development has directed the focus of biochemical research to the proteins in cells in order to gain a better understanding of the role of different proteins and the molecular mechanisms whereby proteins can function and interact with other molecules in the cell.

At the Division of Applied Biochemistry and Biotechnology a number of research projects are being carried out to clarify the functional role of proteins in cells. For example, we are investigating enzymes such as ferrochelatase and magnesium chelatase, which are responsible for the biosynthesis of tetrapyrroles such as haeme and chlorophyll, and enzymes involved in the conversion of natural polysaccharides, e.g. cellulose and hemicellulose. This is important to improve our understanding of how polymers can be converted and used as recyclable resources. Other enzymes are part of large membrane-bound complexes, such as the electron-transporting enzymes in the respiratory chain, crucial for the energy supply to cells. Novel spectroscopic techniques are being developed in order to study such complex proteins. Investigations are also being carried out on other proteins that are not enzymes but play important roles in cells, such as helper proteins (chaperones), which keep other proteins healthy, or allergens, which are troublesome proteins causing allergies. A new project has been initiated on virus biophysics, focussing especially on virus protein capsids as nanocontainers for the packaging and ejection of viral genomes.

We have experience in, and equipment for, genetic engineering of protein expression, purification of biological membranes and membrane proteins, techniques for protein separation and analysis, including the unique aqueous polymer two-phase partition technique, invented at the Division. Advanced instrumentation for proteomics and protein mass spectrometry by LC-MS/MS permits investigation of large numbers of novel proteins, so that specific protein modifications can be identified.

Another field of research at the division is focussed on membranes and membrane proteins. These membranes are semipermeable, and their selectivity is due to transport proteins containing channels specific for, e.g., sugar, water or protons. Other membrane proteins record changes in the environment and initiate reactions to adjust to these changes. We are studying how membrane proteins function, e.g., by determining their structure in great detail. We are also investigating how transport proteins are regulated, e.g., how water channels are opened and closed, or how nutrient uptake in plant roots is changed, all according to the immediate needs.

The living cell makes extensive use of association processes on the colloidal scale as in lipid membranes and organelles. Equally significant is the remarkable stability with respect to colloidal association in these systems, with a multitude of different macromolecular species in a dynamically varying confined volume. This constitutes a huge area of research and we have targeted a number of specific problems, such as DNA compaction/decompaction, molecular transport and protein–lipid interactions.

Molecular Biophysics

The three-dimensional structure of biological molecules, proteins and nucleic acids, provides the key to understanding the mechanisms of their function at atomic level. The Division of Molecular Biophysics is focussing on the analysis of the structure and function of biological macromolecules using the methods of X-ray crystallography and electron microscopy. The Division is also directly involved in the construction and running of the protein crystallography beamlines at MAX-lab, the Swedish synchrotron radiation source. The laboratory is well equipped for modern X-ray crystallographic and molecular biology research.

Among the proteins being studied are enzymes involved in the regulation of iron homeostasis in mitochondria, such as frataxin and ferrochelatase. Enzymes from the polyamine biosynthesis pathway of the tropical parasites Leishmania and Plasmodium, the causative agents of leishmaniasis and malaria, are being studied with the aim of evaluating their potential for the development of new drugs against these diseases.

Inflammation is a major pathological characteristic of a wide array of severe endemic illnesses potentially affecting almost all tissues and organ systems of the human body. These acute and chronic inflammatory diseases represent a severe burden to Western health care organisations and a major challenge to medical research. The leukotrienes (LT) are one central family of eicosanoids specifically implicated in the pathophysiology of inflammatory and allergic disorders, in particular bronchial asthma. One of the central enzymes of LT metabolism, LTA4 hydrolase, has been selected for the design of new inhibitors. Other projects of medical interest include hormone-sensitive lipase, a key enzyme in the mobilisation of fatty acid from stored triglycerides in adipocytes and non-adipocytes. This enzyme has recently been identified as a target for the development of new drugs against type 2 diabetes.

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